International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 9, Issue 1, Feb 2019, 509-522

A FUZZY MULTI OBJECTIVE TECHNIQUE FOR THE QUANTITY TO BE ORDERED ON SUPPLIER

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ABSTRACT

Economic growth and environmental protection are mutually conflicting in nature. Both issues are to be addressed simultaneously in order to sustain green supply chain management. Suppliers and customers have to focus these aspects in deterring their business relationship. An effort is made here to deploy multi criteria technique fuzzy ahp, Taguchi loss function and fuzzy multi objective technique to ascertain the quantity to be ordered on the supplier. Case study is conducted.

The results are impressive.

KEYWORDS: Green Supply Chain, Fahp, Taguchi Loss Function & Multi Objective Technique

Original Article

Received: Dec 18, 2018; **Accepted:** Jan 08, 2019; **Published:** Jan 25, 2019; **Paper Id.:** IJMPERDFEB201949

INTRODUCTION

The objective of the study is to select to be the supplier and quantity to be ordered in Green supply chain using Fuzzy data. As environmental resources are increasingly depleted, the conflict between economic growth and environmental protection has received greater attention from scholars of supply chain management (SCM) (Zhu et al., 2008 [9]; Zhu et al., 2010 [10]; Ala-Harja, and Helo, 2014 [8]). Creative management of a supply chain in the context of sustainable development, with the particular goal of minimizing the environmental impact that suppliers have on end users, is referred to as Green Supply Chain Management (GSCM).

The word "Waste" normally emphasis something around us which should be re-cycle, re-used, reduced or even eliminated, if possible. A giant amount of waste, such as: electronics/electrical items, manufacturing scrap, discarded constructional materials, polymers from daily needs, contaminated oil etc., is being generated day-by-day, whereas its treatment is lagging. The term zero waste (ZW) is continuously encouraging both producers and consumers to adopt sustainable approaches in order to reduce their expenditures as well as to help in making a better world. Zero Waste Manufacturing (ZWM) is believed as a roadmap for the future of manufacturing by which the burning issue of "Waste" can be tackled. However, ZWM can be supported with recycling and reusability of the produced wastes in another manufacturing process, use of optimization tools and sustainable manufacturing theories, development of precision manufacturing systems, etc.

As per the Hazardous Waste (Management, Handling and Tran boundary Movement) Rules, 2008 (HW Rules) "hazardous waste "any waste which by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics, causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances per Schedule IV of the Hazardous Waste Rules, 2008, both used oil & waste oil have been categorized as hazardous waste also listed in Schedule I under the rules [6]. Motor oil is used for lubricating various internal combustion engines to reduce friction, protect against wear and tear and helps in distribution of heat. During normal use, many impurities such as soot, water, acids, dirt, metal scrapings, and chemicals can get mixed in the oil, and becomes ineffective for further application [1,2]. The current disposal practice of just dumping used oils in drains, rivers and lagoons poses serious environmental and health hazards. Thus, it is imperative to find more environmentally sustainable ways to dispose used lubricating oils through recycling. Recycling of the waste lubricating oil is now regarded as the most viable option to address the environmental dangers posed by the indiscriminate waste engine oil disposal. In addition, recycling is also considered as an effective means of conserving the depleting world crude reserve and job creation through the construction and operation of recycling plants [3,4]. Several methods of recycling waste lubricating oil have evolved over time from the period, which recycling of waste oil began during the late 1930s. These methods include; acid method, distillation/clay method, acid/clay method, activated charcoal/clay method among others. Since the inception of waste lube oil recycling, clay has been one of the most important and widely used adsorbent materials for the renewal of the oil [5]. Engine oil recycling chain l comprises waste oil suppliers, distributors, reclaimers, customers' warehouse agents etc. each section of supply chain desires to optimize their resources such that the entire system can be optimized. As it is brought out elsewhere in the paper the ultimate object is zero waste.

Selection of supplier plays a vital role in sustaining the green initiatives towards oil recycling. The characteristics of supplier are selection is a multiple criteria decision-making(MCDM) problem, which is affected by several conflicting factors. Consequently, purchasing manager must analyse the trade-off among the several criteria. MCDM techniques support the decision-makers' (DMs) in evaluating a set of alternatives. Depending upon the purchasing situations, criteria have varying importance, and there is a need to weigh them.

Analytic hierarchy process (AHP) is a widely used decision making tool(developed by city) in various multi-criteria decision making problems. It takes the pair-wise comparisons of different alternatives with respective to various criteria and provides a decision support tool for multi criteria decision problems. In a general AHP model, the objective is in the first level, the criteria and sub criteria are in the second and third levels respectively Since basic AHP does not include vagueness for personal judgments, it has been improved by benefiting from fuzzy logic approach. In fuzzy AHP (F AHP)), the pair wise comparisons of both criteria and the alternatives are performed through the linguistic variables, which are represented by triangular numbers.

Taguchi method was developed by Genichi Taguchi the father of quality engineering, who successfully integrated powerful applied statistical methods into engineering processes for achieving greater stability and capability Taguchi realized and appreciated the vitality of producing an outcome on target and concluded that, excessive variation in performance was the root cause of poor quality and was counterproductive to the society at large. Taguchi loss function (Quality loss function) is a method of measuring loss as a result of the product not meeting the standard specifications (Taguchi, 1989). The purpose of calculating loss is to quantitatively evaluate the quality loss caused by the variation. Loss Function considers the willingness of consumers to obtain a more consistent product and the company's desire to produce

products with low cost. Minimization of losses suffered by consumers is a strategy that encourages uniformity of the products and reduces costs of production and consumption. Taguchi loss is useful for the company to identify not only the rejected and reworked scrap, but also the possibility of environmental pollution, the use of not long-lasting products, or other negative effects. Loss for the company is the cost due to deviation from the target value

LITERATURE REVIEW

Henry Mensah-Brown (2013) has presented technique for the optimization of the production of lubricating oil from re-refined used lubricating oil using response surface methodology. Since the 1990s, the optimization of the supply chain management to take environmental issues into account has been paid increasing attention, including the issue of environmental investment recovery, internal re-design of the supply chain network, green coordination among upstream and downstream enterprises, and green initiatives(Zhu et al., 2007b[12]; Sarkis et al., 2011 [14]; Mitra et al., 2013[15]). Environmental investment recovery aims to encourage waste reduction and foster an attitude of reuse and recycle by means of reverse logistics and remanufacture (Zhuand Sarkis, 2004 [11]). (Sheu et al., 2005 [13]), proposed a linear multi-objective programming model to maximize the net profit of integrated logistics and the corresponding used-product reverse logistics. Abdelkader Sbihi and Richard W. Eglese introduced the area of Green Logistics and to describe some of the problems that arise in this subject which can be formulated as combinatorial optimization problems Today's, global warming and environmental issues are obvious and governments seek to alternative renewable fuels instead of fossil fuels. Among renewable fuels, biofuels because of the direct usable and easy production are highly interested. Fatemeh Ezzati furnished paper. On Optimization of multimodal, multi-period and complex biodiesel supply chain systems' multi-objective mathematical model is presented to select suppliers and allocate orders to suppliers under uncertainty conditions by Ali Mohtashami* & Alireza Alinezhad. In 2013, an interactive solution approach is proposed for multiple objective supplier selection problems with Fuzzy AHP [16]. Their methodology includes three objectives; minimizing total monetary cost, maximizing total quality and maximizing service level. By the provided interactivity, the decision maker has the opportunity to incorporate his preferences during the iterations of the optimization process.

NOTE ON VARIOUS TECHNIQUES USED

Fuzzy AHP

Fuzzy Analytic Hierarchy Process (f-AHP) fuzzy analytic hierarchy process (f-AHP) embeds the fuzzy theory to basic Analytic Hierarchy Process (AHP), which was developed by Saaty [18].

Step 1: Decision maker compares the criteria or alternatives via linguistic terms shown in Table 1

Table 1: Linguistic Terms and the Corresponding Triangular Fuzzy Numbers

Saaty Scale	Definition	Fuzzy Triangular Scale
1	Equally Important (Eq. Imp)	(1, 1, 1)
2	The intermittent values	(1, 2, 3)
3	Weakly Important (W. Imp)	(2, 3, 4)
4	The intermittent values	(3, 4, 5)
5	Fairly Important (F. Imp)	(4, 5, 6)
6	The intermittent values	(5, 6, 7)
7	Strongly Important (S. Imp)	(6, 7, 8)
8	The intermittent values	(7, 8, 9)
9	Absolutely Important (A. Imp)	(9, 9,9)

According to the corresponding triangular fuzzy numbers of these linguistic terms, for example, if the decision maker state "Criterion 1 (C1) is Weakly important than Criterion 2 (C2)", then it takes the fuzzy triangular scale as (2, 3, 4). On the contrary, in the pair wise contribution matrice of the criteria comparison of C2 to C1 will take the fuzzy triangular scale as (1/1, 1/3, 1/2). The pair wise contribution matrice are shown in Eq1. Where $\tilde{d}^{k}_{ij}$ indicates the kth decision maker's preference of ith criterion over jth criterion, via fuzzy triangular numbers.

$$\tilde{A}^{K} = \begin{pmatrix} \tilde{d}^{k}_{11}\,\tilde{d}^{k}_{12} & \ldots\ldots\ldots\ldots\tilde{d}^{k}_{1n} \\ \tilde{d}^{k}_{21}\,\tilde{d}^{k}_{2n} & \ldots\ldots\ldots\ldots\tilde{d}^{k}_{2n} \\ \ldots\ldots\ldots\ldots & \ldots\ldots\ldots\ldots \\ \tilde{d}^{k}_{n1}\,\tilde{d}^{k}_{n2} & \ldots\ldots\ldots\ldots\tilde{d}^{k}_{nn} \end{pmatrix} \tag{1}$$

$$\tilde{A}^{K} = \begin{bmatrix} \tilde{d}^{k}_{11} & \tilde{d}^{k}_{12} \ldots & \tilde{d}^{k}_{1n} \\ \tilde{d}^{k}_{21} & \tilde{d}^{k}_{2n} \ldots & \tilde{d}^{k}_{2n} \\ \tilde{d}^{k}_{n1} & \tilde{d}^{k}_{n2} \ldots & \tilde{d}^{k}_{nn} \end{bmatrix}$$

Step2: if there is more than one decision maker. Preferences of each decision maker ($\tilde{d}^{k}_{ij}$) are averaged and ($\tilde{d}_{ij}$) is calculate as in the Eq. 2.

$$\tilde{d}_{ij} = \frac{\sum_{k=1}^{k} \tilde{d}^{k}_{ij}}{K} \tag{2}$$

Step 3: according to averaged preferences, pair wise contribution matrice is updated as show in Eq. 3

$$\tilde{A} = \begin{bmatrix} \widetilde{d_{11}} & \cdots & \widetilde{d_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{d_{n1}} & \cdots & \widetilde{d_{nn}} \end{bmatrix} \tag{3}$$

Step 4: the geometric mean of fuzzy comparison values f each criterion is calculated as show in Eq 4. Here, $\tilde{r}_i$ still represents triangular values.

$$\tilde{r}_i - \left(\prod_{j=1}^{n} \widetilde{d_{ij}}\right)^{1/n} \quad , i=1,2,\ldots\ldots\ldots\ldots n \tag{4}$$

Step 5: The fuzzy weights of each criterion can be found with Equation 5 by incorporating next steps.

- Find the vector summation of each $\tilde{r}_i$. Find the (-1)' power of summation vector. Replace the fuzzy triangular number. To make it in an increasing order.
- To find the fuzzy weight of criterion i ($\widetilde{w_1}$), multiply each $\tilde{r}_i$ with this reverse vector.

$$\widetilde{w_1} = \tilde{r}_i \times (\tilde{r}_1 \times \tilde{r}_2 \times \ldots\ldots \times \tilde{r}_n)^{-1} \tag{5}$$

$=(lw_i, mw_i, uw_i)$

Step 6: since $\widetilde{w_1}$ are still fuzzy triangular numbers, they need to de-fuzzified by centre of area method proposed by Chou and Chang[50]. Via applying the Eq.6.

$$M_I = \frac{lw_i + mw_i + uw_i}{3} \tag{6}$$

- Mi is non fuzzy number. But it needs to be normalized by following Eq.7

$$\mathrm{N_i} = \frac{M_i}{\sum_{i=1}^{n} M_i} \tag{7}$$

Taguchi Loss Functions

Dr. Genichi Taguchi has developed a set of methodologies for applying statistics to increase process and product quality. Till the recent studies, Taguchi philosophy has-been accepted widely as an effective approach merely for quality engineering and design of experiment. In the last decades, Taguchi loss functions have been used as a MCDM approach. Taguchi loss functions are categorized mainly into three groups as nominal is the best, lower is better and higher is better and the formulations and graphs related to functions are given in

$$L(y) = k(y-m)^2 \tag{8}$$

Where $L(y)$ is the loss associated with a particular quality character y, m is the specification goal, k is the loss coefficient. USL an LCL are the upper and lower specification limits. These notations are also valid for one side loss functions.

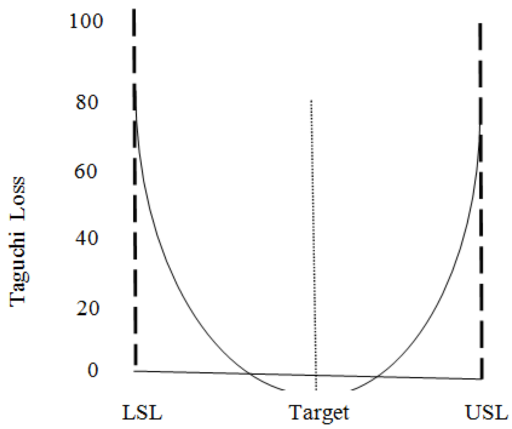

Figure 1

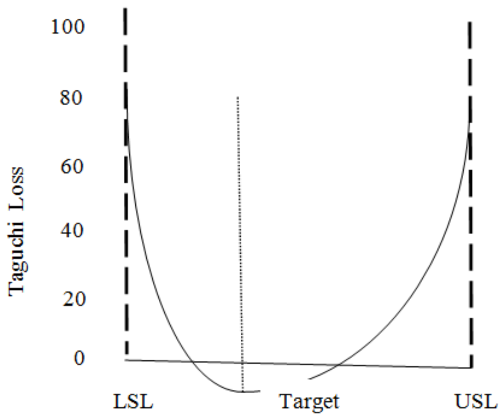

Figure 2

$$L\,(y) = k \times y^2 \tag{9}$$

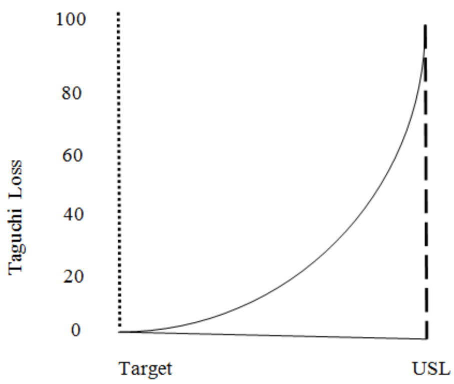

Figure 3: Lower is Better Loss Function

$$L(y) = \frac{k}{y^2} \tag{10}$$

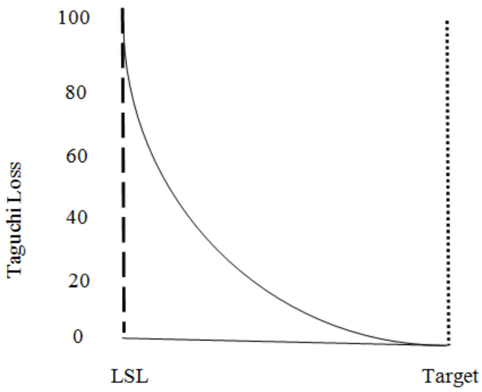

Figure 4: Higher is Better Loss Function

Multi Objective Function

Step1: Solve the multi-objective cost function as a single objective cost function using one objective at a time and ignoring all others. From the results, determine the corresponding values for every objective at each solution derived.

Step 2: from step 1, for each objective, the best L_k and worst U_k value corresponding to the set of solutions the initial fuzzy model can then be stated as, in terms of the aspiration levels for each objective, as follows:

Find Q satisfying $f_k \lesssim L_k,\ k=L, C. R$ subject to the non negatively conditions

Step3: Define fuzzy linear membership function (μ_{f_k}; $k = L, C, R)$ for each objective function is defined

By

$$\mu_{f_k} = \begin{cases} 1; & f_k \leq L_k \\ 1 - \frac{f_k + L_k}{d_k}; & L_k \leq f_k \leq U_k \\ 0; & f_k \geq U_k \end{cases} \tag{11}$$

Step4: After determining the linear membership function defined in (11) for each objective functions following the problem can be formulated an equivalent crisp model

$$\text{Max } w1 * \sum_{k=1}^{k} z_k * \alpha_K + w2 * \alpha_{K+1} \tag{12}$$

$z_{k\,=}$ F(x) for all k;

(zku-zkl)*α_K>

$\alpha \leq \mu_{f_k}(x)$; k= L,C,R

METHODOLOGY

The following steps are followed

Step 1: Framing the relevant criteria for supplier selection

Step 2: Collecting the fuzzy data for each crieteria by field study.

Step 3: Comparison of data by fuzzy AHP method and determination of weights /scores

Step4: Calculation of expected loss using Taguchi loss function

Step 5: Performing the fuzzy multi objective programming to determine the supplier and the quantity to be ordered.

CASE STUDY

This study mainly focuses on the green supplier selection problem of a oil company located in Vijayawada. Four possible suppliers have been determined by the expert. As a result of increasing consciousness of environmental issues and being under pressure from customers' demand, the company tends to incorporate environmental criteria into the supplier selection process. Therefore, the criteria shown in Table have been determined considering green terms based on expert's remarks and findings of the literature review

Fuzzy AHP Method

Regarding the cost criterion, if other conditions are the same, the purchaser becomes interested in buying from those suppliers who propose cheaper prices. In general, quality level has a reverse relation with defective items' ratio. Therefore, high quality level is equal to the low ratio of defective items. Regarding the criterion of delivery time, customers are interested in having the item when they need it (not sooner or later than this time). Delivering the item sooner results in maintenance cost and delivering the item later will be accompanied by shortage cost. Evaluating the criterion of environmental competencies includes the effect of pollution generated and control techniques which consumes money and time; but they are vital for a supplier's success. Environmental competencies include pollution control techniques. Source capacity is the ability of suppliers capacity to meet the demand.

Table 2: Comparative Values of Criteria Terms of Waste Oil Supplier

	Quality	Source Capacity	Cost Charged	Delivery Terms	Environmental Competence
Quality	(1,1,1,)	(1,1,1)	(4,5,6)	(6,7,8)	4,5,6)
Source Capacity	1,1,1,	(1,1,1,)	4,5,6)	(6,7,8)	(6,7,8)
Cost	1/6,1/5,1/4	1/6,1/5,1/4	(1,1,1,)	¼,1/3,1/2	2,3,4
Delivery Terms	1/8,1/7,1/6	1/8,1/7,1/6	2,3,4	(1,1,1,)	1/6,1/5,1/4
Environmental Competence	1/6,1/5,1/4	1/8,1/7,1/6	¼,1/3,1/2	4,5,6	(1,1,1,)

After completing the first three steps of the methodology, at the fourth step, the geometric mean of fuzzy comparative values of each criterion is calculated For example $\tilde{r}_1$ geometric mean of fuzzy comparison values of "Quality" criterion is calculated.

$$\tilde{r}_1 = \left(\left[\prod_{j=1}^{n} \tilde{d}_{ij}\right]\right)^{1/n} = \left[(1*1*4*6*4)^{\frac{1}{3}}; (1*1*5*7*5)^{1/3}; (1*1*6*8*6)^{1/3}\right] = [2.49; 2.81; 3.10] \quad (12)$$

Table 3: Relative Fuzzy Values of Quality Weights

Quality(fuzzy values)	2.49	2.81	3.1
Source capacity	2.7	3	3.29
Cost	0.43	0.53	0.66
Delivery Terms	0.35	0.41	0.49
Environmental Competence	0.46	0.54	0.66
Total	6.43	7.3	8.2
Inverse(1/Col Value)	0.16	0.14	0.12
Ascending Order	0.12	0.14	0.16

$$\widetilde{w_1} = [(2.49 * 0.12); (2.81 * 0.14); (3.10 * 0.16);] = [0.304; 0.385; 0.483] \quad (13)$$

Hence the relative fuzzy weights of each criterion are given Table 3;

Table 4: Fuzzy Weights of All the Criteria

Quality (Fuzzy Values)	0.304	0.385	0.483
Source Capacity (Fuzzy Values)	0.330	0.412	0.511
Cost (Fuzzy Values)	0.052	00.072	0.103
Delivery Terms (Fuzzy Values))	0.043	0.057	0.076
Environmental Competence (Fuzzy Values)	0.056	0.075	0.103

The relative non fuzzy weight of each criterion (M_i) is calculated by taking the average of fuzzy numbers for each criterion.

Ex: for environmental competaence m1 = (.056+.075+.103)/3 =.

- By using non fuzzy Mi ‘s, the normalize weights(Ni)of each criterion are calculated and tabulated in Table 5.

Table 5: Normalised Values of Criteria of Supplier

	M_i	(N_i)
Quality	0.3901	0.383
Source Capacity	0.418	0.409
Cost	0.075	00.074
Delivery Terms	0.058	0.057
Environmental Competence	0.078	0.076

Table 6: Comparison Matrix of Suppliers with Respect to Quality Criteria

	Supplier A	Supplier B	Supplier C
Supplier A	(1,1,1,)	1/6,1/5,1/4	1/9,1/9,1/9
Supplier B	4,5,6)	(1,1,1,)	¼,1/3,1/4
Supplier C	9,9,9	2,3,4	(1,1,1,)

Table 7: Fuzzy Weights of Suppliers with Respect to Quality

	Supplier A	Supplier B	Supplier C
Supplier A	0.265	0.281	0.303
Supplier B	1	1.186	1.442
Supplier C	2.621	3	3.302
Total	3.885	4.47	5.047
Inverse(1/Col Value)	0.25	0. 22	0.19
Ascending Order	0.19	0.22	0.25

Table 8: Average and Normalized Weights of Suppliers with Respect to Quality

	M	N
Supplier A	0.064	0.063
Supplier B	0.27	0.272
Supplier C	0.68	0.665

Table 9: Normalized Weights of Suppliers with Respect to Various Criteria

	Quality	Source Capacity	Cost Charged	Delivery Terms	Environmental Competence
Supplier A	0.063	0. 425	.629	.149	0.62
Supplier B	0.27	0.425	.107	.784	.107
Supplier C	0.66	0.151	.26	0.06	.263

Taguchi Loss Function

Table 10: The Specification Limit and the Range of 5 Decision Making Criteria for Supplier Selection

Criteria	Target Value	Range	Specification Limit
Quality	0%	0-(-2%)	2
Source capacity	0	0-7%	7%
Cost	The least price	0-(-12)%	20%more
Delivery Terms	100%	60-100%	60%
Environmental Competence	100%	85-100%	85%

Table 11: Each Supplier's Taguchi Loss Coefficient Calculation.

	Target		Specification	Taguchi Coefficient k
Quality	100	1	2	250000
Source capacity	100	1	7	2.040816
Cost	100	1	20	2500
Delivery Terms	100	1	60	36
Environmental Competence	100	1	85	138.4083

Ex for quality taguchi loss coefficient = 100/(.02 *.02) = 250000 similarly for source capacity, cost, environmental competencies. Whereas for delivery terms 100 *.6 *.6 =36

Table 12: Suppliers Taguchi Loss Parameters

	Supplier A	Supplier Loss Value	Supplier B	Supplier Loss Value	Supplier C	Supplier Loss Value
Quality	1.7%	72.25	1.5%	56.25	1.6%	64
Source	2	8.16	1	2.046	3	18.36
Cost	0	0	0.15	56.25	0.2	100
Delivery	0.95	39.88	0.85	49.82	0.97	38.26
Environmental competence	0.9	112	0.96	127	0.92	117.

In the final step of Taguchi loss function, each supplier’s total loss in relation with each criterion has been obtained based on the following formula:

$$loss_j = \sum_{i=1}^{n} w_i \ c_{ij}$$

After the calculation of loss coefficient based on Taguchi formula and the specification of the loss function type and also the specification of the supplier's value in each criterion, each supplier's loss has been obtained based on the table.

Table 13: F-AHP Value (Brought Down)

Quality	0.383
Source capacity	0.409
Cost	00.074
Delivery Terms	0.057
Environmental Competence	0.076

Table 14: Each Suppliers Total Loss: Taguchi Loss Normalization with Respect to Supplier

	Quality		Source Capacity		Cost Charged		Delivery Terms		Environmental Competence		Total Loss	Normalised
Supplier	**Weight**	**Taguchi Loss**		**Taguchi Loss**		**Taguchi Loss**		**Taguchi Loss**		**Taguchi Loss**		
A	.383	72.25	.409	8.16	.074	0	.057	39.88	.076	112	42	0.32
B	.383	56.25	.409	2.04	.074	56.25	.057	49.82	.076	127	39	0.29
C	.383	64	.49	18.36	.074	100	.057	38.26	.076	117	52	0.39

Ahp weights used in above table

Fuzzy Multi Objective Formulation

The amounts of purchasing each of these items from each of these suppliers are calculated.

Quality score objective(scores obtained from table 9)

Max z1 =0.063 *x1 +0.27 *x2 +0.66*x3

Source capacity score objective(scores obtained from table 9)

Max z2 =0.425 *x1 +0.425 *x2 +0.151*x3

Cost score objective(scores obtained from table 9)

Max z3 =0.629 *x1 +0.107 *x2 +0.26*x3

Delivery terms objective(scores obtained from table 9)

Max z4 =0.149 *x1 +0.784*x2 +0.06*x3

Environmental objective(scores obtained from table 9)

Max z5 =0.62*x1 +0.107 *x2 +0.263*x3

Taguchi loss value objective(scores obtained from table 9)

Max z6 =0.32 *x1 +0.29 *x2 +.39*x3

Total purchase limits

X1 +x2+x3 >0;

X1 +x2 +x3 <100000;

Individual supplier Capacity

X1>25000;x2>30000;x3 <40000;

Each individual objective is solved and the results are shown in the table.

Table 15: Individual Objective Function Max Values along the Values of Other Function at that Criteria

	Max Z1	Maxz2	Maxz3	Maxz4	Maxz5	Maxz6	Difference
Z1	37425	26997	26997	31965	26997	35535	10428
Z2	31540	35376	35376	35376	35376	31540	3836
Z3	29870	40256	40256	27728	40256	35090	12528
Z4	33565	28461	28461	43701	28461	27215	16486
Z5	29765	38893	38893	27581	39893	34895	12312
Z6	33750	33070	33070	32350	33070	34050	1700

Aspiration levels(α) for each objective function are calculated as shown in methodology. Individual objective functions are converted into crisp function as shown below.

Crisp objective function:

Max w1 *(0.383* α_1 +.4098α_2+.074*α_3+.o57*α_4+.076*α_5) +w2*α_6

Summation of weights

w1 +w2 =1;

α_1* $10428 \; + \text{z1} \; - 37425 > 0$;

α_2*$3836 \; + \text{z2} \; - 35376 > 0$;

α_3 *$12528 \; + \text{z3} \; - 40256 > 0$;

α_4*$16486 \; + \text{z4} \; - 43701 > 0$;

α_5*$12312 \; + \text{z5} \; - 39893 > 0$;

α_6*$1700 \; + \text{z6} \; - 34050 > 0$;

$\alpha_1 \geq 0$; $\alpha_2 \geq 0$; $\alpha_3 \geq 0$; $\alpha_4 \geq 0$; $\alpha_5 \geq 0$; $\alpha_6 \geq 0$;

$\alpha_1 \leq 1$; $\alpha_2 \leq 1$; $\alpha_3 \leq 1$; $\alpha_4 \leq 1$; $\alpha_5 \leq 1$; $\alpha_6 \leq 1$;

X1≥25000;x2≥25000;x3 ≥26000;≥

W1 =.8

The equations are solved using lingo software. The quantity of oil in liters to be orders on each supplier is below

Answers

Supplier 1 : 25000 unit

Supplier 2 :36000 units

Supplier 3 :39000 nits;

Table 16: Actual Objective Values

	Objective Function Values(lts *scores)
Z1	37035
Z2	31814
Z3	29717
Z4	34289
Z5	29609
Z6	33650

CONCLUSIONS

Many researchers and scholars have mentioned the advantages of green supply chain management for environmental sustainability. Creating a close and long term relation between the supplier and purchaser is one of the key elements of supply chain creation success to obtain competitive advantage.. Therefore, the issue of supplier selection is the most important issue in effectively implementing supply chain.

On the other hand, the issue of supplier selection in general faces imprecise and ambiguous data and using the theory of fuzzy sets in considering this kind of uncertainty seems logical.

To this end, decision making approaches such as FAHP were used in this research; which employed a fuzzy approach which can be considered close to real data. The later Taguchi loss function is employed for quality loss calculation. The multi objective function is deployed to ascertain the quantity to be ordered by simultaneously optimizing supplier parameters such as quality, cost, delivery etc.. Sensitivity analysis demonstrates the possible variations of the preference level of the most important three criteria regarding criteria weights which can be carried out by changing the weights. Further research might be investigating the integrity of other MCDM approaches with Taguchi loss functions. Another research direction might be to develop a decision support system where appropriate suppliers and order sizes can be determined in succession

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